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Hydrogeochemical Characterization and Evaluation of Groundwater Quality in Anumula Province of Semiarid Region, Telangana State, India

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Abstract:
The objective of the work is to hydrochemical characterisation and evaluation of groundwater quality in Anumula province of Nalgonda district of Telangana state. The province, which spans 192 km² and is located in a semiarid environment with water scarcity and groundwater quality issues. In the year 2018, groundwater samples were collected at 47 stations and were analysed for their chemical composition. Based on hydro-chemical facies depicted through a piper diagram that Ca-Mg-HCO3 type of water predominates in the study area. The major ion data showing that groundwater is contaminated with fluoride (27.6%) and nitrate (21.2%) of samples have beyond the permissible limits of WHO recommended values for drinking purpose. The data of USSL diagram, residual sodium carbonate, sodium adsorption ratio, salinity hazard and sodium percent depict that the groundwater is suitability of water for irrigation use in the region. This study further indicating that groundwater should be treated before use for drinking while for irrigation purpose it can be used with due attention.

Keywords: *Hydrochemical characterisation, Groundwater quality, Anumula province.*

1. INTRODUCTION

Groundwater is fundamental item which is broadly taken advantage of normal asset and presently confronting serious contamination needs its quality evaluation for use for drinking reason. Poor groundwater quality seriously affects occupations and climate, and consequently feasible administration of groundwater assets required extraordinary concern (Kadam, 2021). In semi-dry and parched districts element like lopsided precipitation, huge evapotranspiration, serious disintegration, and continuous human exercises have become irregularity among organic market of water assets is very unmistakable (Zhou et al. 2020). The attributes of groundwater substance advancement are the concentrated impression of ecological change is of extraordinary worry for groundwater asset and natural quality development (Sunil Kumar and Ramanathan, 2008; Pillai et al. 2020). Groundwater assists enormously in refining the proficiency of the water with involving in water system regions which can oblige far more prominent fluctuation popular from famers, especially during dry spell or dry season when water system water is basically required (Bauder et al., 2008).

Groundwater quality expects importance in choosing the utilization of groundwater for a specific explanation. Water for drinking should be liberated from hurtful parts, over the top minerals that might influence human prosperity

(Reddy et al., 2019; Vaiphe and Kurakalva, 2021). Productive perception is significantly required on the grounds that all human medical conditions are clearly associated with water quality. Normal and anthropogenic variables impact groundwater physical and compound examples in a space, accordingly weakening the quality (Subramanian 2009; Khatri and Tyagi, 2015). Groundwater has a more conspicuous separation substance due to its extended participation with different materials in the geologic layers (CPCB, 2007) nearly with surface water. The objectives of the study are to study hydrogeochemical characteristics and evaluation groundwater quality for its suitability for drinking and irrigation purposes.

2. MATERIALS AND METHODS

2.1 Geology of study area

Anumula province, which spans an area of 192 sq.km and has a population of 63,740, is situated in the southeast of Telangana state between 16^o 43' 30" and 16^o 55' 30" North latitude and 79^o 12' 00" to 79^o 24' 00" East longitude (Figure 1). Agriculture, horticulture, and animal husbandry workers are the main employers. Granitic gneiss, composed of weathered and broken granites, serves as the province of Anumula's principal aquifer. In the research area, groundwater is produced by the worn and cracked neisses granite under water table conditions. Geologically, the studied region is a component of the Indian Peninsular Shield and is composed of Archaean and Proterozoic formations, which are distinguished by rocks from the Peninsular Gneissic Complex or the Basement Complex. The oldest formations are known as the Archaeans, which were deposited in shallow basins and later invaded by basic rocks. Dolerite dykes and veins of pegmatite and quartz were later found intruding into the gneisses and granites. Rocks from both Archaean and Proterozoic formations may be found in the research region, which gives it its distinctive characteristics.

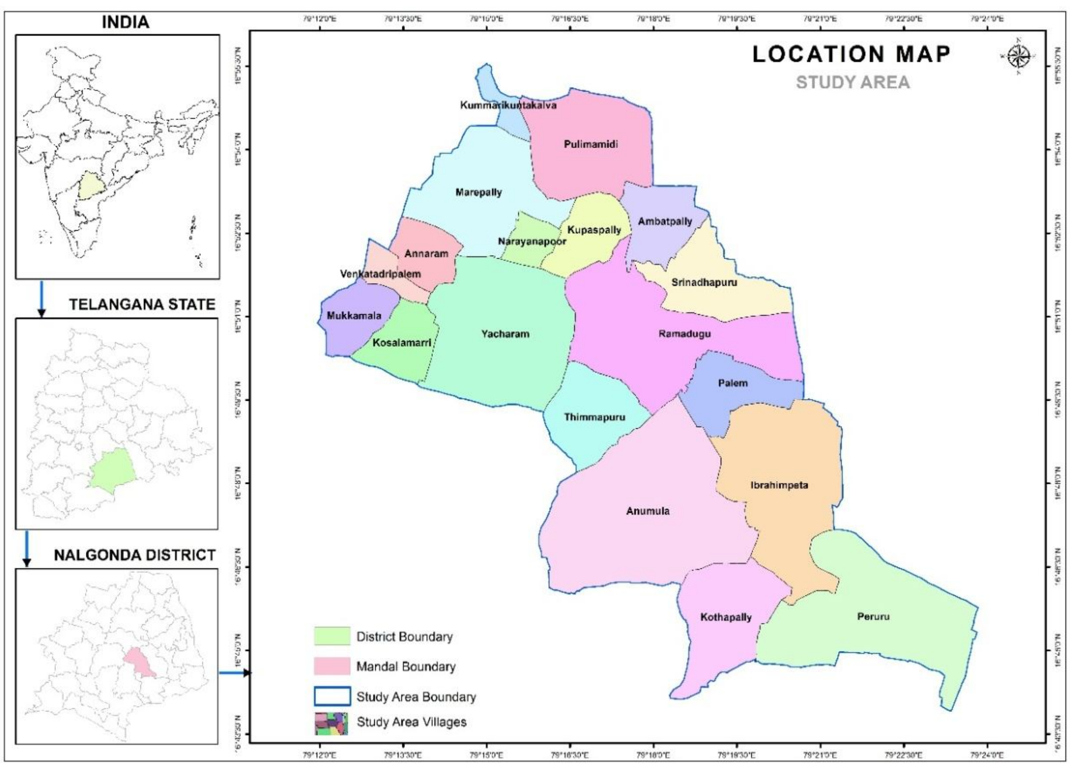

Figure 1: Location map of Anumula province of Nalgonda district, Telangana state

Granites, gneisses, schists, and intrusives make up the 90 percent of the district's Archaean crystalline rocks. 9% of the southern half of the district is made up of the consolidated metasedimentary rocks of the Cuddapah and Kurnool system, which include limestones, quartzites, and shales. Unconsolidated deposits made mainly of alluvial sands and clay are found in isolated and small patches along the major rivers and streams, making up about 1% of the total area.

2.2 Groundwater samples and analytical methods

During the pre-monsoon season (May 2018), groundwater samples were collected at 47 locations throughout the rural province of Anumula province (Figure 2). For a chemical character study, the collected water samples were placed into a polythene container that had already been cleaned. Usual procedures advised by APHA (2017); chemical analysis were performed to determine the principal ion concentrations of the water samples taken from various places. The chemical properties of ground water are influenced by the analytical data used to categorise water for different uses and to determine numerous factors.

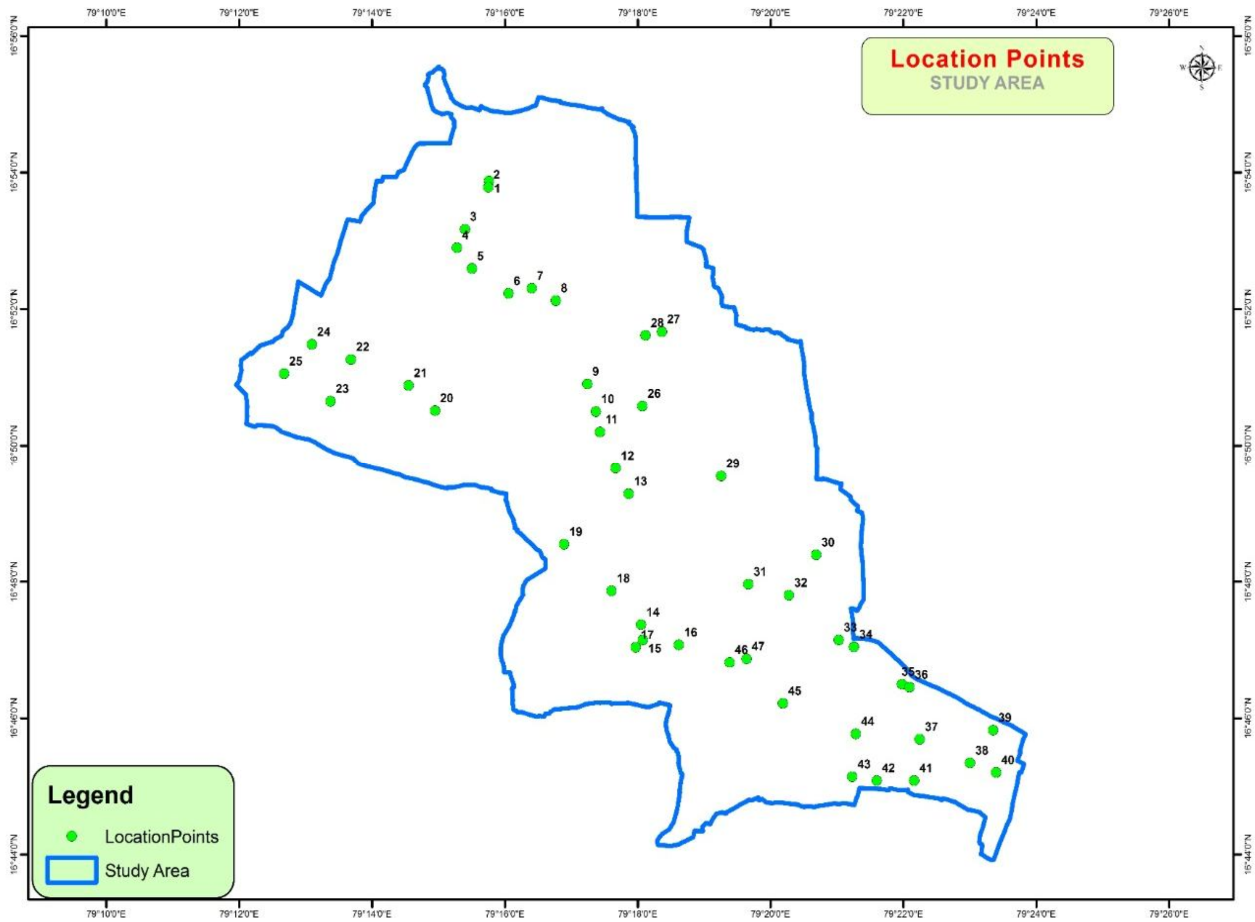

Figure 2: Groundwater sampling locations from the study area

3. RESULTS AND DISCUSSION

3.1 Hydrochemical characterization

Table 1 shows the most extreme and least groupings of the significant particles that were found in the groundwater from the examination region. To decide the hydro-geochemical facies of ground water, use the Flute player outline (Flautist, 1953). Two triangles are available in these plots, one for diagramming cations and the other for anions. A solitary point in a jewel formed field is made by joining the cation and anion fields, from which decisions about the hydro-geochemical facies can be made. Rather than other potential plotting strategies, these tri-straight graphs are advantageous in featuring compound connections among groundwater tests in additional exact terms. Plotting the compound data of delegate tests from the review region on a Flute player tri-direct graph (Figure 3). The possibility of hydrochemical facies was made to grasp and arrange the water organization in different classes. Facies are recognizable actual attributes of different characters in any hereditarily associated framework. Anion and anion concentration categories are found in hydrochemical facies, which are separate zones. During the pre-monsoon, water of the Ca-Mg type predominated and accounts for 40% of the samples were Ca-Mg types. The hydro-chemical facies did not significantly alter during the study period, proving that the majority of the major ions are naturally occurring. The cause is that because igneous rocks' composition is relatively insoluble, groundwater travelling through them only partially dissolves mineral materials.

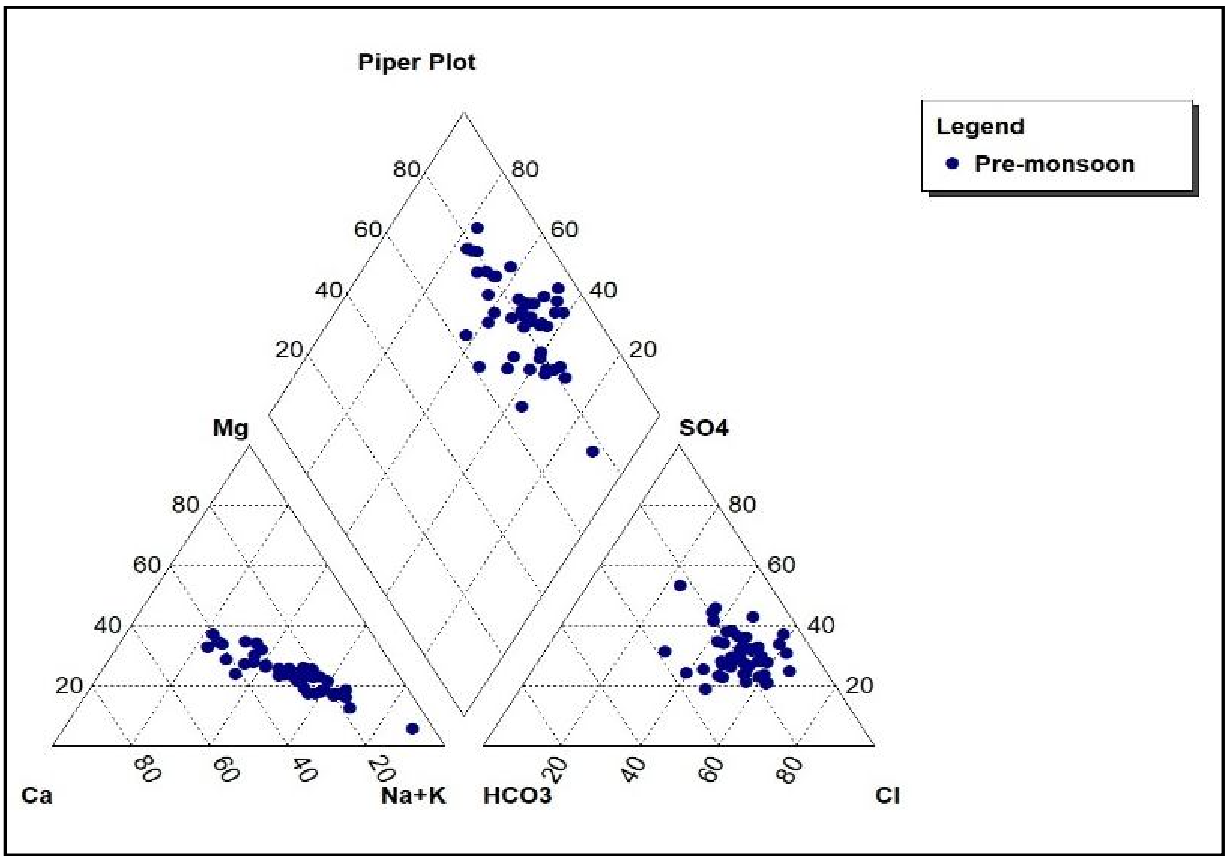

Figure 3: Piper trilinear diagram

3.2 Drinking water quality

The anions like carbonate, bicarbonate, chloride, and sulphate as well as cations like calcium and magnesium are major contributors to water hardness. Although water hardness has no known negative effects, some research suggests that it may play a part in heart disease and unsuitable for residential usage is hard water (WHO, 2012). Table 1 shows the groundwater classification based on electrical conductivity (EC), total dissolved solids (TDS) and total hardness (TH).

Table 1: Groundwater classification based on electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), nitrate and fluoride. (n=47)

Parameters	Range	Classification	No of samples exceeding allowable limits	Percentage of samples exceeding allowable limits
EC (µS/cm) After Todd	<250	Excellent	Nil	Nil
	250 -750	Good	5	10.63
	750-2000	Permissible	34	72.34
	2000-3000	Doubtful	4	8.51
	>3000	Unsuitable	4	8.51
TDS (mg/L) (Davis and Dewiest, 1966)	<500	Desirable for drinking	6	12.76
	500-1000	Permissible for drinking	22	46.80
	1000-3000	Useful for irrigation	19	40.42
	>3000	Unfit for drinking and irrigation	Nil	Nil
TDS (mg/L) (Freeze and Cherry,1979)	<1000	Fresh water type	28	59.57
	1,000-10,000	Brackish water type	19	40.42
	10,000-100,000	Saline water type	Nil	Nil
	>1,00,000	Brine water type	Nil	Nil
Total Hardness (mg/L)	<75	Soft	Nil	Nil
	75-150	Moderately high	3	6.38
	150-300	Hard	19	40.42
	>300	Very hard	25	53.19

Table 2 represents the permissible limits of all parameters with reference to WHO (2012) recommended values for drinking purposes. This data shows that fluoride and nitrate are exceeding 27.6% and 21.2% of samples are beyond the permissible limits respectively. Fluoride content in the groundwater might be due to dissolution of fluoride bearing minerals in the study region. Besides the nitrate content in the groundwater might be due to agricultural activities in the area. The spatial distribution of fluoride (Figure 4) showed that most of the area has found 1mg/l fluoride and some pockets elevated concentrations (> 2mg/l) observed. Beside nitrate (Figure 5) concentration mostly found in northwest and south east regions where more agricultural activity identified, hence it might be due to fertilizers used in the crop protection enhancement or improvement.

Table 2: Permissible limits of all parameters reference to WHO standard showing minimum, maximum, and average values.

Parameters	Concentration (mg/l)			WHO (2012) desirable limit		Samples exceeding permissible limit (mg/l), WHO (2012)
	Min	Max	Average	Mg/l	No. of Samples	% of Samples
Physicochemical						
pH	6.3	8.9	7.3	7-8.5	Nil	Nil
EC	549.3	3915	1511	750-1500	22	46.8
TDS	352	2506	967	500-1000	7	14.9
TH	76	735	325	100-500	4	8.5
Anions						
F^-	0	3.5	1.2	0.6-1.5	13	27.6
Cl^-	77	675	242	250-600	2	4.2
HCO^-_3	39	385	171	20-600	Nil	Nil
SO^{2-}_4	47	559	188	250-400	2	4.2
NO^-_3	4	210	44	45	10	21.2
Cations						
Na^+	43	412	160	50-200	15	31.9
K^+	1	56	10	100-200	Nil	Nil
Ca^{2+}	15	146	71	75-200	Nil	Nil
Mg^{2+}	9	90	36	50-150	Nil	Nil

The total hardness in Anumula province fall in hard category around 40.4% and very hard category around 53.1% indicating not suitable for drinking. Groundwater samples classified according to Sawyer and McCarty (1979) as hardness range 49% of water samples are belongs to brackish water, whereas 40% samples are not useful for drinking purposes as Davies and Deweist (1966) (Table 3).

Table 3: Groundwater classification to assess its suitability for irrigation purposes

Parameters	Range	Classification	No of samples exceeding allowable limits	Percentage of samples exceeding allowable limits
Sodium (%)	<20	Excellent	Nil	Nil
	20 -40	Good	13	27.66
	40-60	Permissible	24	51.06
	60-80	Doubtful	9	19.15
	>80	Unsuitable	1	2.1
RSC	<1.25	Good	47	100
	1.25-2.5	Doubtful	Nil	Nil
	>2.5	Unsuitable	Nil	Nil
Sodium Hazard	S1 0-10	Excellent	46	97.9
	S210-18	Good	1	2.1
	S318-26	Doubtful	Nil	Nil
	S4 and S5>26	Unsuitable	Nil	Nil

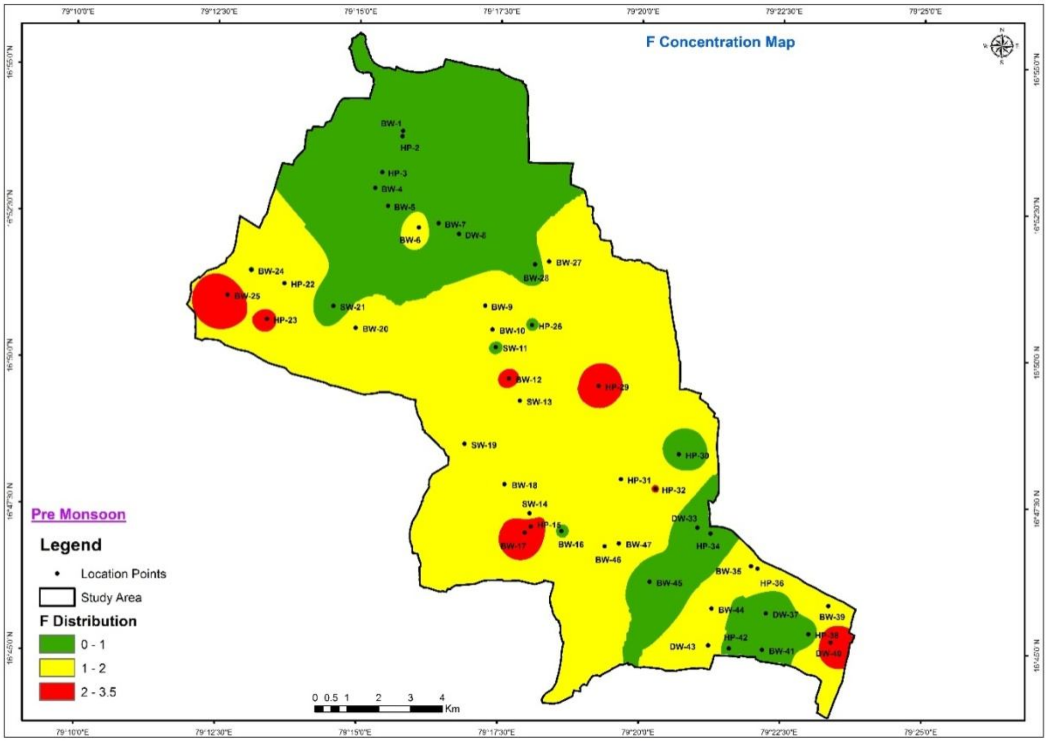

Figure 4: Spatial distribution of fluoride in groundwater

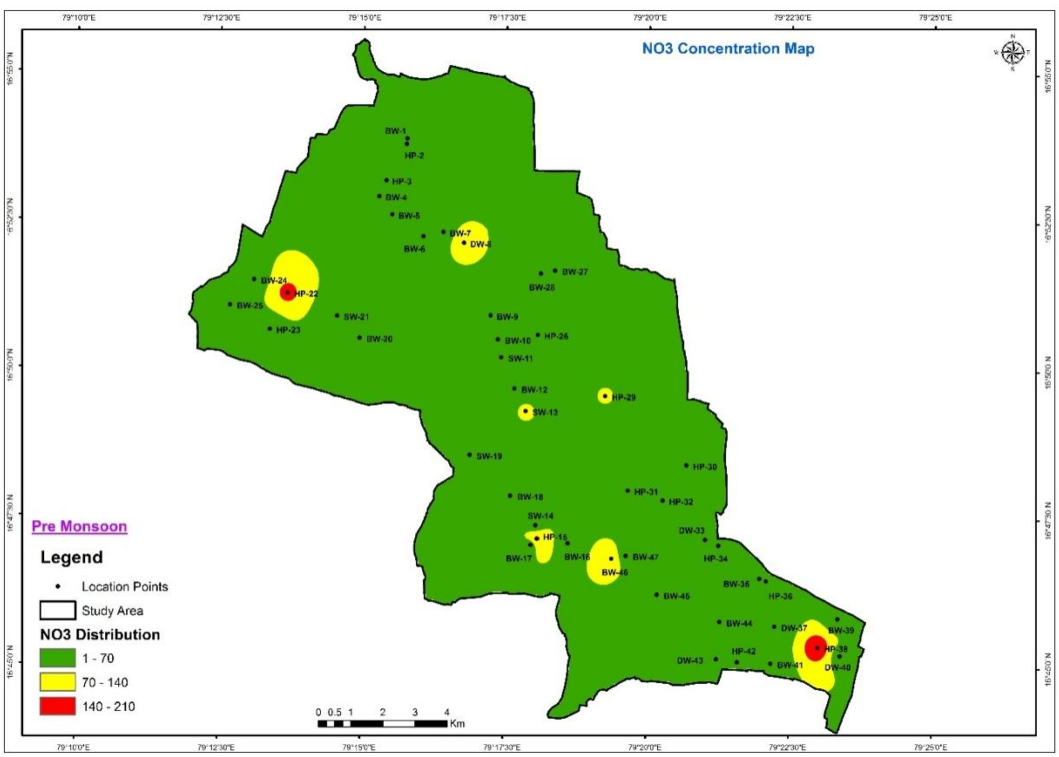

Figure 5: Spatial distribution of nitrate in groundwater

3.3 Irrigation water quality

The minerals that make up groundwater to find out its suitability whether or not be used for irrigation purposes. The following most general standards are used to evaluate its quality, they are (i) electrical conductivity (EC)-measured total salt concentration (ii) SAR's measurement of the relative fraction of sodium to other main cations, (iii) bicarbonate (HCO_3^-). Groundwater for irrigation was categorised by Wilcox (1948) based on electrical conductivity and sodium content. Eaton (1950) suggested using the residual sodium carbonate concentration to gauge the water's viability for irrigation. The US Salinity Laboratory of the Department of Agriculture adopted a few methods that explain why water is suitable for agriculture.

The following formula can be used to calculate the sodium content in irrigation fluids, which is often expressed as a percentage of sodium (Wilcox (1948)

$$\% Na = (Na+) X 100 / (Ca^{+2} + Mg^{+2} + Na^{+1} + K^{+1})$$

Where, Ca+2, Mg+2, Na+, and K+ concentrations are reported in milliequivalents per litre (Meq).

Various irrigation quality indices were calculated and presented in Table 3. Sodium content in 19% of the samples are doubtful for irrigations however 27.66 and 51.06% samples are in good and permissible category respectively demonstrated found suitable for irrigation. As the water in the soil gets more concentrated in waters with high bicarbonate concentrations, calcium and magnesium have a tendency to precipitate. The outcome is a rise in sodium carbonate, which is the relative amount of sodium in the water. Utilizing the following equation, RSC is determined.

$$RSC = (HCO3- + CO32-) – (Ca2+ + Mg2+)$$

Where, all ionic concentrations are expressed in Meq.

Water with more than 2.5 epm of RSC is not acceptable for irrigation, according to the US Department of Agriculture. The RSC is used to categorise the groundwater in the research area, and the findings are shown in Table 3. All the samples have RSC values that are less than 1.25, indicating suitable for irrigation purposes.

The most urgent variables in surveying the nature of water system water are (I) the all out convergence of solvent salts, (ii) the general extent of sodium to other head cations, (iii) the grouping of boron or one more possibly harmful component, and (iv) the centralization of bicarbonate when contrasted with the convergence of calcium in addition to magnesium. These have been alluded to as the bicarbonate risk, sodium peril, saltiness danger, and boron risk (Wilcox, 1959). The sodium danger has recently been expressed as a level of all cations. The SAR, which is utilized to communicate soil reactivity, is a superior mark of the sodium water system danger. The SAR is determined as

$$SAR = \frac{Na^+}{\left\{ \frac{Ca^{2-} + Mg^{2+}}{2} \right\}^{1/2}}$$

Where, all ionic focuses are communicated in epm

Table 3 shows how groundwater samples from the study area were categorised in terms of SAR. All most all samples (98%) are had SAR values of less than 10, which are considered excellent for irrigation. The categorization of water for irrigation can be established by graphically projecting the SAR and specific conductance of the water on the US salinity (USSL) diagram (Figure 6). Majority of the samples are fall into the C3S1 and C3S2 classes (Figure 7). Anumula province's groundwater is often of the Ca- Mg-HCO3 type, which is mostly attributable to the region's igneous rocks of a crystalline form, the primary units of which are gneisses and granites. In the research area, groundwater is produced by the worn and cracked Gneisses granite under water table conditions.

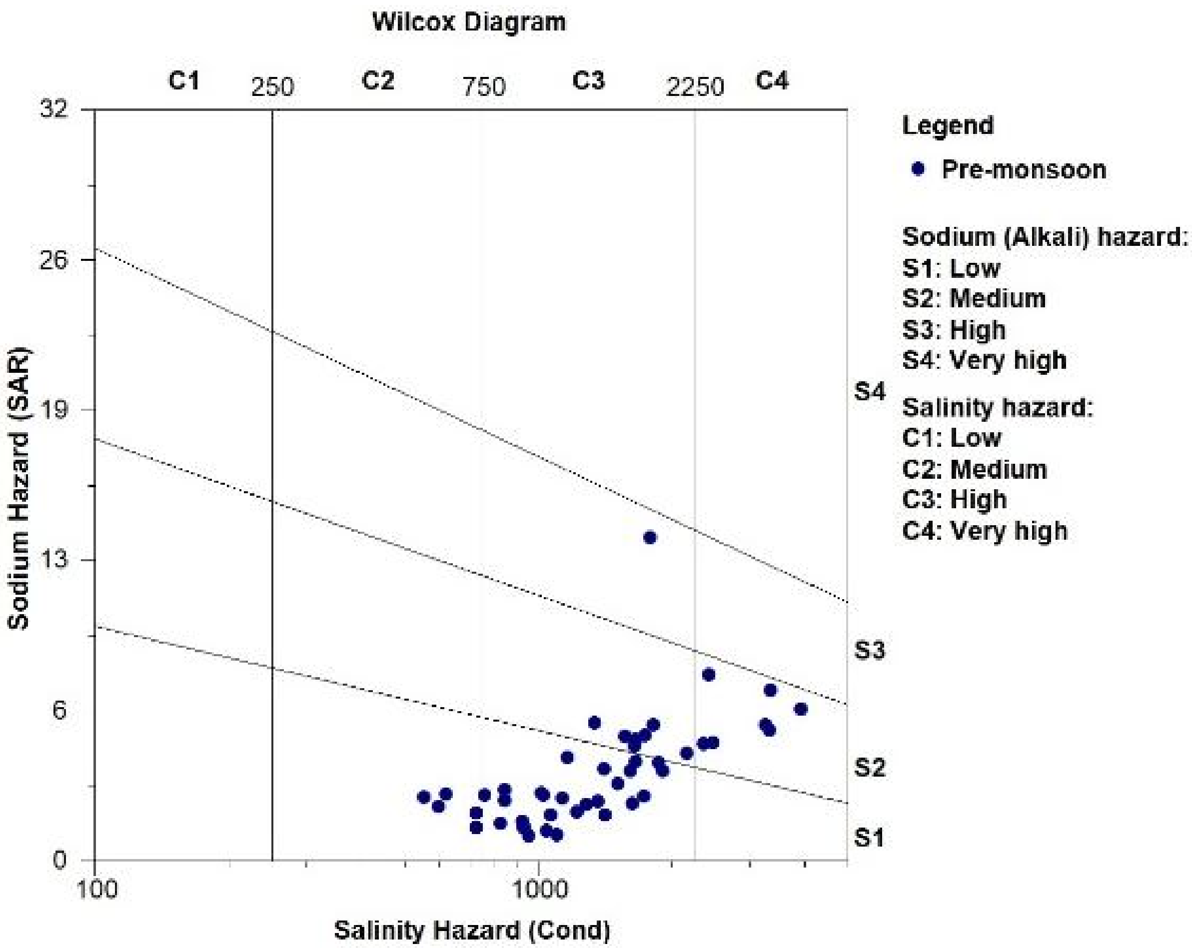

Figure 6: USSL classification of groundwater

4. CONCLUSIONS

The hydrogeochemical data found that the groundwater is predominates Ca-Mg-HCO3 hydro-chemical facies in the study area. The groundwater of study regions are contaminated with fluoride and nitrate around 27.16% and 21.2% respectively. In some pockets elevated fluoride concentration indicated that the dissolution of fluoride bearing minerals. Hence prior treatment is essential to supply the groundwater for drinking purposes. Various irrigation suitability indices calculated indicated that groundwater in the studied region is more suitable for agricultural activities. The flexibility of water is significantly affected by different variables, such soil type, crop type, crop example, recurrence and re-energize (precipitation), environment, etc. It is advised little attention required as 19% samples are in doubtful category as per % sodium content in groundwater.

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6. CONFLICT OF INTEREST

The authors declare no competing interests.

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